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similar to those of the higher river valleys of the interior ; and these later beds extended along the coast northward, to and over the Amazonian region. The uniformity in character of these beds, over so immense an area, is something very remarkable. South of Rio I have not examined them ; but they occur south of Brazil, on the plains of the Argentine Republic.

VIII.—At the time when the drift sheet was deposited, the land certainly stood at a much greater elevation than at present ; for, in the vicinity of the Cantogallo Railroad, I have seen the drift extending down to sea level ; and the same is true at Bahia. Drift clays and boulders are found over the whole coast so far north as Pernambuco, according to my own observations ; but Prof. Agassiz describes the drift as occupying the whole valley of the Amazonas.

IX.—After the drift, there occurred a depression of the coast to a level, at Victoria, of about eight feet below our present sea-level. The land remained at this level for a short period, and then began to rise, laying bare and raising beaches and shore deposits, and adding to the coast considerable areas of swampy and low land, especially at the mouths of rivers ; the beach ridges which form the present sea line were thrown up, and the stone and coral reefs were accumulated. The recent upheaval of the land I believe to be still in progress, my belief being based upon the shading off, in point of preservation, of the untenanted nests of the sea-urchins, in going upward from the zone of living sea-urchins on the rocky shores. The decomposition of the gneiss and other rocks of the coast has taken place since the drift.

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V.—*Polar Magnetism. Its Astronomical Origin ; its Period of Revolution and the Synodical Period of our Earth Identical.* By JOHN A. PARKER.

Delivered March 18, 1869.

In a paper published by me, as read before the Society of the American Institute in March last, on the subject of Polar Magnetism, I showed, from the records of the variations of the compass for nearly three hundred years past, that the Magnetic Pole, in its movement westward, had in that period

passed over more than one hundred and sixty degrees of longitude in its revolution round the North Pole, or Geographical Pole of the Earth.

The reasoning on this subject appearing to be conclusive that the Magnetic Pole revolves about the North Pole, we were naturally led to the inquiry, what is Polar Magnetism? and what is the cause of this revolution? Those who have read my published paper on this subject with care will know that our solution of those questions was in effect: that the forces of magnetism and gravitation are identical; that the force which directs the needle to the Pole is wholly astronomical; that the source of the governing attraction is from the highest centre to which the Earth in her various revolutions is immediately related; that the revolution of the Earth relatively to that centre is the cause of the apparent revolution of the Magnetic Pole; that the period of the revolution, as indicated by the recorded variations of the compass, is about six hundred and forty years, more or less, to be determined; that the Earth in that period, as a satellite of the Sun, performs a revolution round the Sun relatively to the central point of the Sun's orbit, exactly similar to that which our own satellite, the Moon, performs in her synodical period, in which she revolves about the Earth, relatively to any given meridian, from opposite the Sun's centre (the central point of the Earth's orbit) to opposite that centre again.

These are our main positions, which we are bound to prove by direct and unequivocal evidence, and also to defend and sustain against all contrary evidence which the ingenuity and skill of scientific men may bring against it.

If these things shall prove to be true, a reviewer has said, "they will rank among the most daring and felicitous in the annals of scientific discovery;" and if I may be allowed the expression of my own judgment in the matter, taken with all their adjuncts, they will prove as useful for the extension of knowledge as any scientific discoveries ever made.

Before we proceed further, however, to illustrate and prove our own theory, it may be well to examine the position which the science of the schools at present occupies on this subject. We shall do so disembarrassed of the technicalities with which scientific men have surrounded the general subject, and which, as I believe, are a bar to their own progress and discovery. It must be recollected, however, that we are not discussing the general principles of magnetism, or its abstract quality, nor the particular properties of magnets, or the nu-

merous experiments to which they have been subjected, and which have occupied so large a share of the attention of scientific men ; our subject limits itself and all inquiry to that paramount law, which, local and disturbing influences apart, at all times and in all places claims the direction of the needle to the Pole. We must therefore confine our remarks to what is at present understood in the schools in respect to this branch alone of magnetic phenomena.

From the earliest date of discovery of any change in magnetic attraction, it became a subject of inquiry by what law these changes were governed. For a very long time knowledge was confined to the observations of a few individuals in limited spheres ; and these served little purpose except to establish the fact that changes were taking place, but without being able to assign any reason for it. Explorers and navigators finally became the largest contributors to the knowledge of the world on this subject. By visiting almost every accessible part of the globe, and reporting their observations at home, a vast amount of facts were furnished for the use of investigators ; as these discoveries increased, the manifest importance of the subject enlisted the aid of governments in the interest of the schools, and the last half century has witnessed a more extended effort than ever before, if possible to discover the laws of polar attraction. For this purpose the observations of all time have been brought together, and the minds of eminent men have been engaged, to see what results could be obtained from the facts thus collected.

These results can be soon stated. It has been discovered that there is a line surrounding the globe, bisecting the terrestrial Equator at an angle of twelve or fourteen degrees, which they have called the Magnetic Equator. It is that line where the needle has no inclination or dip, but rests perfectly horizontal. It requires the minutest possible observation to be able to locate it within a degree or more of latitude.

As at present indicated, it passes over the wide continent of Africa, where no observations at all have been had. It passes over the widest portion of South America, where very few observations have been had, and it passes over the kingdom of Siam and the Island of Borneo, where there have been no surveys at all. To supply the deficiency of observations over all these regions and wide intermediate tracts of ocean, other means were resorted to in their endeavors to locate the Magnetic Equator throughout. It was discovered that the inclination or dip of the needle increased in nearly

a regular progression as we proceed northward from the line of the Equator towards the Magnetic Pole, and this fact was made use of with apparent good judgment to assist in determining the locality of the Magnetic Equator, and consequently also of the Magnetic Pole. But when, by careful calculation from all the premises and ascertained facts at hand, the Equator was supposed to be determined, it was found to be no Equator at all—that it was wholly irregular and without symmetry, and hence of no use whatever in determining any truth relatively to itself or to the Magnetic Pole. Nothing discouraged, however, by the want of success, the eminent men and scholars engaged in the work have enlarged their labors; they have collected together all the observations made to this end in every part of the world, both those which are recent and for a long series of years past; they have divided the globe into eastern and western hemispheres, in reference solely to the east and west variations of the needle, and they have covered the globe as it were with the lines produced from the observations so collected; but all without success to discover a law which should govern polar attraction and thus point to the Pole itself.

The same course of reasoning is still being pursued, and scientific men in Europe and America are engaged in collecting new observations, and drawing lines as deduced therefrom—lines of declination, of inclination, and intensity—lines parallel, convergent, and divergent—lines in fact of every imaginable name and description, with a view to determine accurately the position of the Magnetic Equator at any given time with its corresponding Pole, and the laws which govern their changes as observed from time to time; and I need not say that all this has been without success for the objects intended. The only positive knowledge which these exertions have given us, is a knowledge of the facts which explorers have communicated, but with no law whatever to govern them;—no two theories agree in their results. Humboldt, who may be supposed to have been among the most learned in theory, placed the Magnetic Pole by calculation in latitude  $79^{\circ}$  north and  $27^{\circ}$  west, almost at the same time when Ross found it by practical observation to be situated approximately in  $70\frac{1}{2}^{\circ}$  north and  $96^{\circ}$  west. Where there is so great a discrepancy between fact and theory, there is necessarily a fundamental error either in the theory itself or in its manipulation.

Whatever of truth and sound reason there may be in the use made by scientific men (and there is, no doubt, very

much of both) of the facts in their possession in this regard, their inevitable failure from inherent causes to arrive at true results is, I think, manifest.

*First.*—Because the facts from which they reason, for want of means to distinguish, necessarily include the disturbances due to the sensitiveness of the needle, but which do not belong to the law of polar attraction.

*Second.*—The changes going on are such that, with their method of applying facts, that which was true a year ago is not true at the same point to-day.

*Third.*—Many, and indeed most of the facts collected together, and which form the material of their work, are facts determined by observations made by different persons, and at different times, so wide apart, that, although all of them were perhaps true at the time and place of observation, yet only one of them could be true at the same time, and not one of them is exactly true to-day.

*Fourth.*—It is self-evident, I think, that no true result can ever be arrived at by the method of imaginary lines, unless the facts on which such lines are based could be determined in all parts of the world at the same time, which has never been done and does not admit of a possibility.

In all the experiments of scientific men, they have regarded the Earth as the source of magnetism. Not a half century ago, many of them considered the Earth as a fixed magnet, and all magnetic influence was referred to that cause; but the changes observed contradicted that idea, and they have latterly imagined magnetic veins running through the Earth, which they have endeavored to trace by lines drawn upon its surface. To account for the changes going on, these veins have been supposed to be shifting, so as to accommodate the veins to the changes. Some have gone so far as to imagine a constant circulation of the molecules or atomic principles composing the Earth, thus producing the changes of the magnetic tendency. The celebrated Arago treated this idea with seriousness.

It has been observed that temperature, the aurora borealis, and other natural phenomena, have an influence on the magnet, and it is doubtless true; but these influences being a part of the general law of magnetism, they do not touch that

paramount law which claims the direction of the needle as soon as these influences are removed.

The Sun's heat is supposed to cause the daily vibration of the needle—the periodical return of spots on the Sun have been supposed to have an influence on the declination of the needle, and some one has suggested that the Moon has such influence also, but by *no one, before myself, has it ever been advanced that the cause of polar attraction is wholly astronomical.*

I have thus given as full and true a statement of the condition of science in the schools on the subject of polar magnetism as our limited time and space will permit. I would remark that revolution as a cause or accompaniment of magnetic attraction was not heard of among them till since the publication of my pamphlet in March last. Since that time the *Cornhill Magazine* of June, the *Scientific American* of October, and *Silliman's Journal* of November, have each of them published an article indicating revolution, but without any acknowledgment of my paper, though it was sent to all of them.

We now turn to our own hypothesis, as explained in the opening paragraph of this paper :

In all inductive reasoning on physical laws, there are truths in nature which may be laid down as axioms, from which the reasoning admits of no departure, and I therefore here lay down as axioms—*First*, that the laws of mechanics are the laws of nature. *Second*, that the construction of the universe, and the relations of the heavenly bodies to each other, and of our Earth to them, *is Nature herself*, and consequently in the relations of the heavenly bodies to each other, and of our Earth to them, we shall find the perfection of all mechanical laws. I think there can be no objection to these principles.

The question has been asked me by some intelligent persons, whose perceptions were not quite clear on the subject, “by what mechanical process the revolution of the Magnetic Pole around the North Pole can be accomplished by astronomical attraction.” I will therefore give an illustration, which I have given before at a private reading of my first paper on the subject, and which I think explains it.

Let us suppose that the globe before us is transparent in such a way as to admit a line of light passing through it. Let us then suppose that a single ray of light, emanating from some distant centre, shall strike the globe at twelve or fourteen degrees from either Pole, and passing through the centre of the globe at an angle to its axis in a line to the

opposite side. It is seen that the ray of light will make a point on either side of the surface of the globe, each at the same distance from the geographical Poles, but at opposite angles to the globe's axis. Now let the globe revolve eastward on its axis : it is seen that the ray of light is stationary, but the points of light on the surface appear to revolve westward, while the globe is revolving eastward.

Now if you let the ray of light represent the line of attraction from the great centre around which our hypothesis assumes that the Earth is revolving, you will have a perfect mechanical idea of the revolution of the Magnetic Pole around the geographical Pole, caused by astronomical attraction, with this difference only, that whereas the ray of light appears to revolve with each revolution of the Earth on her axis, the Magnetic Pole only revolves in that period of time in which the Earth gains one complete year in moving eastward round the Sun, just as we gain one entire day when we travel eastward round the Earth, and just as the Moon, in moving eastward round the Earth, gains one revolution of the Earth on her axis, and just as the Earth, in moving round the Sun from opposite a fixed star to opposite that star again, gains one sidereal day.

Now let us observe that if the cause of the revolution of the Magnetic Pole be such as I have described, viz., attraction to a higher centre relatively to which the Earth is revolving, then *because* the Earth moves eastward on her axis and in her orbit, therefore, by the mechanical law which is our axiom in the case, the apparent revolution of the Magnetic Pole SHALL BE WESTWARD—and that the Magnetic Pole is known to have been moving westward for nearly three centuries, is a positive proof as far as it goes of the truth of our hypothesis ; whereas if the Earth be the source of magnetism, as the schools teach us, this effect would be mechanically impossible. This is one of the many phenomena that confirm the truth of our theory, and we may safely ask the question, can anything be shown to the contrary sustained by an equal mechanical test of its truth ?

The irregularities heretofore observed in the variations of the needle (and I would include *inclination* with *declination*) which have baffled inquiry, and led to the conclusion by many, that it was not governed by any law definable by reason, are, in my judgment, when examined upon their merits and aside from local and disturbing causes, a perfect evidence of the revolution of the Magnetic Poles, their equable motion through space, and the astronomical influence controlling

their apparent motion. I will mention a few facts illustrative of that view, and in doing so I will keep to the axiom of mechanical truth and necessity.

London is situated in latitude  $51^{\circ}$  north, and the present declination of the needle there is about  $20\frac{1}{2}^{\circ}$  west. The Island of New Nantucket or Baker's Island in the Pacific is in longitude  $176^{\circ}$  west, nearly on the opposite side of the globe from London, and in latitude  $13^{\circ} 30'$  north,—the variation or declination there in 1866 was  $9^{\circ} 30'$  east, or less than half that at London. Why then, being so nearly on the opposite meridian to London, has it not the same amount of variation east that London has westerly? Chiefly for the reason that being farther south, if a circle be described from each centre (London and Baker's Island) through the Pole, the radius of the circle described from Baker's Island is more than twice as long as that described from London, and the length of a degree in the circumference of such circle is more than twice as great, and consequently, the Poles being nearly fixed points, the variation is less than half as great at Baker's Island as at London.

Again, we suppose the Magnetic Pole to revolve in about  $76^{\circ}$  north. London is situated in  $51^{\circ}$  north and New York in  $41^{\circ}$  north. We at New York are therefore more than one-third farther from the line traversed by the Magnetic Pole than London is—consequently, for the reasons explained above, the variation or declination at New York can never attain to a greater amount than something less than two-thirds of the greatest variation observed at any time at London.

The greatest westerly variation ever observed at London was in about the year 1818 equal to  $24\frac{1}{2}^{\circ}$ —the greatest therefore it can ever attain at New York will not exceed about  $15$  or  $16^{\circ}$  west. But if we move northward on the meridian of New York to the latitude of London, the variation there (local causes aside) will always be precisely the same as at London whenever that point stands in the same position as London relatively to the Magnetic Pole, and will attain to the same extent as the greatest observed at London ( $24\frac{1}{2}^{\circ}$ ) whenever the Magnetic Pole shall reach the meridian of  $90^{\circ}$  west of it.

Again, it will be evident that although the Magnetic Pole moves through its orbit with a nearly equal motion (and entirely so except the small daily and yearly revolution), yet the variation of the needle changes much more rapidly at some times than at others at the same point, and very un-

equally at different points at the same time. The cause is easily seen. Whenever the Magnetic Pole is on any particular meridian, as of London, for example, it moves almost at a right angle to that point, and the variation increases rapidly; but before the Magnetic Pole reaches the meridian of  $90^\circ$  from the point of starting it moves at an angle so small relatively to the point of observation, that any increase of variation is scarcely perceptible, and as the change of variation becomes slower at London it becomes faster at New York. We have but to trace the motion of the Poles on the lines of the globe to have ocular demonstration of all these truths.

Similar apparent discrepancies exist in regard to *inclination* as well as the "variation" or declination, and from not dissimilar causes.

It has been quoted to me, for example, that my theory of the revolution of the Magnetic Pole cannot be true, because from the records of the observed *inclination* at London it had changed but little more than  $6^\circ$  in 140 years, and at that rate it would take 7,900 years to complete a revolution; but if we examine the mechanical effect of inclination upon the principle of the revolution of the Magnetic Pole, we shall soon see what inclination has to do with the latter. Inclination in north latitude is simply the downward tendency of the north end of the needle, which increases in a ratio not exactly determined as we proceed northward from the line of no inclination towards the Magnetic Pole. At the Pole the inclination is  $90^\circ$ .

Now, on the supposition of the revolution of the Magnetic Pole, it is self-evident that the inclination at London will be greatest when the Magnetic Pole is nearest, and least when it is farthest off. The Pole will be nearest when it is on the meridian of London, and farthest off when on the meridian of  $180^\circ$  from London.

As the Pole moves westward from the meridian of London, variation or declination will begin at zero and increase, and *inclination* will begin from its maximum point to diminish until the Pole reaches  $90^\circ$  of longitude, when variation will begin to diminish, and both *variation* and *inclination* will go on diminishing until the Pole reaches  $180^\circ$ . Thus we see that in obedience to the requirements of revolution, inclination has been diminishing at London from 1740 (the earliest record) to the present time. It must continue to diminish till about 1983, when the Pole shall reach  $180^\circ$  west from London. It will be seen also, that from the maximum to the

minimum of inclination indicates half a revolution of the Magnetic Pole, and from the minimum to the maximum the other half; but the maximum at London can never reach  $90^\circ$ , because London is never at the Magnetic Pole, and the minimum can never descend to zero, because London is never  $90^\circ$  of a circle of the globe from the Magnetic Pole.

These remarks might be continued almost indefinitely, and with appositeness to the case; but I trust that I have said enough to show that the seeming irregularities which have heretofore baffled inquiry, are in fact a necessity, and perfectly regular when applied to the revolution of the Magnetic Pole, and their existence is therefore the best proof we can have of the truth of our theory, so far as a perfect explanation of their apparent irregularities is concerned.

But our principles involve much higher truths than the apparent irregularities of magnetic attraction, which it is proper that we should state here. They claim that magnetism and the attraction of gravitation are identical *in fact*. They are known to be so in the *degree* of their forces, and since nothing whatever is professed to be known of what causes gravitation, and since by its equality of force magnetism is seen to be capable of doing all that gravitation is supposed to do, the evidence is all in favor of their identity.

*Secondly.*—Our principles involve the necessity that all planets are magnetic, and hence their attraction one to another, and hence that attraction towards the Earth which governs the revolution of the Magnetic Pole.

The Earth being a planet and magnetic, it is justifiable to assume that other planets are magnetic also. I think their relative motions and reciprocal influences demonstrate this truth, and if magnetism and gravitation are identical, it is impossible to be otherwise.

Our Earth, on which we reside, is a lower order of planet—it is a centre to itself and to its own satellite, but to none else. All motion from that centre is therefore necessarily outward from that centre, onward and upward in an ascending ratio from the lower to the higher; as, of the Earth on her axis, the Moon about the Earth, the Earth and Moon together about the Sun, and the Earth, Sun and Moon about a higher centre. In obedience to the axiom of mechanical law, the ascending ratio must also be in strict geometrical progression, for geometry is neither more nor less in this case than exact mechanical proportion. Geometry is pure mechanics, and the one cannot be separated from the other. The period of the Earth, Sun, and Moon is the third in the

ascending ratio as above named, and consequently the third also in geometrical progression. These facts being admitted, we are prepared to prove the period of the revolution of the Magnetic Pole by proving the period of the Earth's revolution relatively to the highest centre to which in her various revolutions she is immediately related.

In my work on the Quadrature, published in 1851, after demonstrating the circumference and diameter of one primary circle to be as 20612 to 6561, and the motion of three gravitating bodies to be as four to three of one primary circumference, I then establish the following geometrical proportion, viz.: "As one primary circumference of a circle is to the Moon's time round the Earth, so is the Moon's time round the Earth to the Earth's time round the Sun (see the Quadrature, page 114 in practical questions, and proposition 4, page 130); and the proportion stands thus: (the Moon's time round the Earth being 27.482666+) 20612 : 27.482666 :: 27.482666 = 366.43555, which, pointing off three figures for units in consequence of the increase of diameter of the circle, is the number of revolutions the Earth performs on her axis in revolving about the Sun (the time being circular time), and this period it will be seen is the second in the order of ascension as we have before described. The *third*, which is our *period* of the revolution of the Magnetic Pole, will then stand as follows: 20612 : 366.43555+ :: 366.43555+ = 651.4409+, the revolutions *being years* instead of *days*, and this I believe to be the exact period of the revolution of the Magnetic Pole around the Geographical Poles of the Earth.

The brevity of this demonstration will not probably suit the judgment of those gentlemen learned in astronomical science as at present taught, who, following the angular system of their predecessors of more than twenty centuries, have developed nothing definitely relative to any period such as we have here given. We must, therefore, for our own satisfaction as well as theirs, examine this period a little more minutely, that we may see what is its significance apart from and beyond its government of the motions of the Magnetic Pole.

As I have said in my last published paper on this subject, "this is not the Sun's period—that, of course, is much greater." The question then comes home with force, what period is it? and I answer, that it is the EARTH'S SYNODICAL PERIOD—a period never calculated, if indeed at all considered by astronomers—a period in which the Earth as a satel-

lite of the Sun repeats on a grander scale exactly the same phenomenon which our own satellite the Moon performs every time she makes a complete revolution of the Earth relatively to the Sun's centre.

In this period the Moon having the Earth for the centre of her orbit, and starting from a point where she conjoins the Sun's centre (which is the centre of the Earth's orbit) with any given meridian on the Earth, she pursues her journey round the Earth till she conjoins with the Sun's centre and that same meridian again; and this is her synodical period. She conjoins with no two meridians, however, at the same instant, but with every meridian on the Earth's surface in the course of one revolution of the Earth on her axis; and this is the highest revolution of the Moon which is exclusively her own, and once completing this, she goes on repeating it forever, following the Earth round the Sun.

So also the Earth having the Sun for the centre of her orbit, and starting from a point where she conjoins with any given meridian crossing the Sun's equator and the centre of the Sun's orbit, she pursues her journey eastward round the Sun till she conjoins with the centre of the Sun's orbit, and that same meridian on the Sun's surface again. And this is the Earth's synodical period in revolving about the Sun. She conjoins with no two meridians, however, on the Sun at the same instant, but with every meridian in the course of one revolution of the Sun on his axis; and this is the highest revolution of the Earth which is exclusively her own. After this she goes on repeating the same forever, following the Sun in his orbit round his great centre.

We have given the Earth's synodical period as 651.4409+ years.\* The Moon performs her synodical period round the

\* From the solution of the problem of three gravitating bodies as shown by the Quadrature, pages 100 to 116, there results a series by which the Earth's synodical period is reached as the fourth in order from one primary circumference, the same as it is the third in order by geometrical progression.

For example, let C be the primary circumference of a circle (20612.), then C plus  $\frac{1}{3}$  = D plus  $\frac{1}{3}$  = E plus  $\frac{1}{3}$  = F plus  $\frac{1}{3}$  = G. Then G = 651.4409+, which, pointing off three figures to the left for years, is the Earth's synodical period.

To show the direct connection of this series and this period with solar time, take the following example: Let C=1, then C plus  $\frac{1}{3}$  = D plus  $\frac{1}{3}$  = E plus  $\frac{1}{3}$  = F plus  $\frac{1}{3}$  = G, then G = 3.160493+ to infinity. Now G is found to be exactly equal to the circumference of one solar day in its relation to the circumference of one diameter; hence  $G \times 5153$ , the area of one primary circle, and  $\div 5184$ , the unit of one solar day as evolved by the multiple 6, will give 3.1415942+ to infinity, equal to the decimal circumference of one diameter. It is therefore competent from this series to produce the circumference of one

Earth in a little more than twenty-nine and a half revolutions of the Earth on her axis from opposite the sun's centre to opposite that centre again, or twenty-nine and a half solar days (it is  $29.530588+$ ).

If therefore we give to the Sun the same number of revolutions on his axis, relatively to the centre of his orbit, from one conjunction to another (and he can have neither more nor less without breaking the order of revolution), it will prove that the Sun revolves on his axis relatively to the centre of his orbit once in twenty-two years and twenty-one days. Any fixed spot on the Sun's disc will therefore return in eleven years and ten and a half days from the time of its disappearance, or in half a revolution of the Sun on his axis relatively to the centre of his orbit. Herschell in his *Astronomy* gives the periodical return of the Sun's spots as eleven and eleven one-hundredths years—equal to eleven years and thirty-nine days. Herschell did not claim to know anything of the period which we are endeavoring to prove; but the coincidence of time of the return of the Sun's spots abundantly proves its truth. But as the Sun's individual spots are not clearly identified, and some may doubt the entire accuracy of time, we will not rest our evidence here—we have a more sure testimony in what follows.

The Sun appears to revolve on his axis relatively to us in twenty-six or twenty-seven days. It is therefore certain that the above revolution of plus twenty-two years relatively to the centre of his orbit must be accomplished by a small daily procession over mean or sidereal time. Herschell gives the Sun's synodical period on his axis (*i. e.* relatively to the Earth and the Moon) as  $27^d\ 5^h\ 5'$ . The Moon's sidereal time round the Earth is  $27^d\ 7^h\ 43'\ 3''$ ; at that rate, therefore, according to Herschell, there is a precession of the Sun on his axis of  $2^h\ 38'\ 3''$  in a sidereal lunation. We have thus the right amount of the Sun's precession in his axial motion relatively to us to conform to the period of  $22+$  years relative to the centre of his orbit. More exactly I think the amount of that precession is  $5^h\ 43''\ 32'''$  daily, equal to  $2^h\ 36'\ 25''$

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diameter from any number whatever, and to any number of places of figures required, and with the use of any equal multiple or divisor of the primary circle and the solar day. This series may also be made a perfect test of the truth of my ratio of circumference and diameter, and of the deficiency of geometers' ratio which it is not in the power of numbers or geometry to disprove. Many of these things, which are considered by mathematicians as mere curiosities of figures, are in fact mechanical truths of the very highest order.

57''' in a sidereal lunation, differing from Herschell's period but 1' 37'' in a lunar month.\* At that rate of motion, in plus twenty-two years, the Sun by his precession will gain one complete synodical period of the Moon and one precession added; and the Earth, having passed twenty-two times round the Sun, will have gained of solar time twenty-two times the amount of one precession of the Sun on his axis, the whole together equal to  $32^{\circ} 0' 51''$ . This is just as it should be; the motion is perfectly mechanical, and the time agrees with Herschell's demonstration of the Sun's precession within a few minutes in plus twenty-two years. Neither one of these phenomena could exist without the other—they are in fact creative of each other; the existence of the period creates the precession, and the existence of the precession proves the necessity of the period.

I consider the evidence perfect in itself, and it is therefore certain, I think, that plus 651 years is the Earth's synodical period, and that the sun turns on his axis relatively to the centre of his orbit once in plus twenty-two years, in which, revolving about the Sun, the Earth conjoins with any meridian on the Sun, and the centre around which the Sun revolves. The fact that this same period is or is not also the period of the revolution of the Magnetic Pole turns wholly upon the admission or denial whether or not the attraction of the needle is caused by astronomical or planetary influence. If that be admitted, it is then an absolute necessity that the superior attractions which govern the Earth's motions relatively to the Sun and the centre of his orbit, must also govern the movement of the Magnetic Pole.

If I understand correctly the principles and necessities of combined motion, these orbs revolving together and about each other, all governed by the same laws, and their forces all equalized between themselves in respect to their relative magnitudes, distances, and velocities, can no more fail to make these conjunctions in the ascending and progressive order exactly as begun, without getting out of place in respect to each other, than the hands of a clock can fail to con-

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\* Whatever difference there may be in the relative motions of the Sun on his axis and of our Earth, it being the primary of all relative motions, it can be neither more nor less than unit, and the unit of circumference irrespective of magnitude is 20612, which expressed in the divisions of time =  $5^{\circ} 43' 32'''$ , which I assume, therefore, is the true difference in the relative motions of the Sun and our Earth on their respective axes; and I prefer this as a principle of motion rather than the result of Herschell's instrumental observation, which, like all other observations, is at best only a very close approximation.

join at 12 m. without getting out of place in respect to time. The perfect observance and exact fulfilment of this order is in fact a part of the law which keeps the Earth in her perfect balance, fulfilling her seasons in exact time, and with perfect safety.

I must here ask attention to the fact that in proving the exact period of the revolution of the Magnetic Pole, I have at the same time explained and proved the Earth's synodical period—a period not before known or understood in the science of the schools—and this is done chiefly by the aid of the Quadrature, so long condemned by the schools as a useless question.

I consider the evidence perfect in itself; yet I have no doubt but it will be rejected by those who contend for the orthodox and angular system of demonstration, which in my opinion is incompetent to discover the truth in either case. The true and immediate reason of its rejection, however, will be, that its simplicity and truthfulness to nature does not flatter the ostentatious pretensions of speculative learning. *Victory*, however, will not always hang in the balance, but must eventually be declared on the side of truth.

There is another truth of Astronomy with which this period has something to do—it is the precession of the equinoxes.

Two forces are always active in revolution; and in order that revolution may be continuous it is necessary that one of the forces should always precede the other a little. Wherever there is continuous revolution, therefore, there is always a precession of one of the forces which govern it. It is a universal principle and a mechanical law, without which motion cannot be continued. It may be best illustrated by the steam-engine, and it is just as observable and necessary in the motion of the heavenly bodies as in the steam-engine.

In the construction of the engine one of the first difficulties encountered was to overcome the force of gravity. It was found that when the two forces of gravity and steam-power came exactly opposite each other the engine stopped. Something was wanted to carry forward motion beyond the centre of gravity, and this is exactly the same thing as precession in the motion of the heavenly bodies. Ingenuity and perseverance at length overcame the difficulty with the steam-engine, and it is a remarkable fact and worthy of attentive consideration, that the principle by which the difficulty is overcome is precisely the same as is observable in the relative motions of our Earth and the heavenly bodies, viz. : by a slight difference in

time in the action of one of the forces,—a moment's precession of one force over the other. Thus, as we have just now seen, the Sun, the source of the governing attraction in his revolution on his axis, takes precession of the Moon in his orbit more than five minutes daily, and fulfils his revolution more than two hours sooner in a lunar month than the Moon completes her orbit relatively to a fixed star.

The Earth appears to be moving between two forces—the attraction of the Sun as the centre of the solar system to which the Earth belongs, and a force outside of the solar system which controls and limits the sidereal or mean year. But in the motions of the Earth the Sun's attraction always takes precedence, or has the precession, because, as I suppose, that the Earth is nearer to him than to the opposite force, and because the Earth undoubtedly belongs to the Sun's system.

Thus, while the Earth is turning on her axis, the Sun actually goes before, and the Earth is nearly  $3' 56''$  longer in turning on her axis from opposite the Sun's centre to opposite that centre again, than she is in turning from opposite a fixed star to opposite that star again. The Earth in her daily revolution is thus carried forward beyond the gravitating centre of the two forces, the solar and sidereal, and the amount which she is thus carried forward is the Sun's daily precession.

Again, in the Earth's revolution round the Sun the Sun arrives at his solstitial points nearly forty-five seconds before the star arrives at the same meridian, and the solar year is ended before the sidereal year is ended; and this again is the Sun's annual precession at his solstitial points over sidereal time, or the mean year.

So also the Sun arrives at his equinoctial points about  $3\frac{1}{2}$  seconds of time and plus  $51''$  of a degree before the star arrives at the same meridian, and this is what is termed the "precession of the equinoxes," in which, according to our theory, the Sun by his precession carries the Earth beyond the centre of gravity of the two forces which govern her motion; and this precession will surround the globe in about 25,000 years, sometimes called the great year of the Earth.

We are now to see what our period of the revolution of the Magnetic Pole and the Earth's synodical period has to do with the precession of the equinoxes.

In my work on the Quadrature, pages 97 to 99 inclusive, I have shown that "all periods of time are greater than the

revolution of one primary circle in space, because all the heavenly bodies by which time is measured are themselves also in motion." The revolution of one primary circle in space when reduced to time is 23h. 51' 23'' 20'''— and the sidereal revolution is the exact mean between one circular and one solar day, less 44'' 52''', which is the Sun's precession at his solstitial points. In other words, the excess above the mean between a circular and sidereal and a sidereal and solar day is the Sun's precession at his solstitial points.\*

As the Earth's synodical period is the same revolution as her annual period, only continuous for a longer time, and relatively to a higher centre, which is on a scale of geometrical progression above the annual period, it is, therefore, evident that the Sun's daily precession in the Earth's synodical period shall be the *mean of the difference* between a circular and sidereal and a sidereal and a solar day, and any excess of the actual period above the mean of such *difference*, shall be the Sun's precession at his equinoctial points. In this we follow the exact rule as seen to exist in the annual revolution and the Sun's precession at his solstitial points.

The actual mean as described above, is found by calculations to be 2' 9'' 10''' solar time,† and the actual time of the Sun's daily precession in the Earth's synodical period is 2' 12'' 37''' + ‡ the difference above the mean is 3' 27''' +,

* The solar day equals 24 hours, difference greater than circular day.....	8' 36'' 40'''
The sidereal day equals 23 h. 56' 4'' 6''', difference less than solar day.....	3 55 54
The circular day equals 23 h. 51' 23'' 20''', difference less than sidereal day.....	4 40 46

Excess of difference above the mean ..... 0' 44'' 52'''

† The difference between one circular and one sidereal day is 4' 40'' 46''', half equals.....	2' 20'' 23'''
The difference between one sidereal and one solar day is 3' 55'' 54''', half equals.....	1 57 57

Together = .....	4' 10'' 20'''
Half equals .....	2 9 10

‡ The period 651.4409 + × 365.24225 +, the days and fractions of days in the mean year, gives the product 237933.74 +, equal the number of solar days in the whole period; and this product 237933.74 + divided into the mean year reduced to the smallest appreciable divisions of time (thirds, or 60ths of a second) will give the required Sun's precession daily to accomplish the whole revolution. Thus, 651.4409 + × 365.24224 = 237933.74 + and 365 d. 5 h. 48' 50'' 53''' reduced to its lowest denomination = 1893415853 ÷ 237933.74 = 7957.74 +, which is the amount of the Sun's

which is the Sun's daily precession above the mean as before stated; and because in performing one complete revolution round the Sun, the Earth has gained one entire revolution on her axis from the Sun to the Sun, or one solar day, therefore the Sun, on the completion of the full year, arrives at his equinoctial point preceding the star by exactly the excess ( $3'' 27''' +$ ) of the whole daily precession above the mean of the DIFFERENCE between a circular and sidereal and a sidereal and solar day, as before stated,—just as at his solstitial point, the Sun precedes the star by exactly the excess above the mean between a circular and sidereal and a sidereal and solar day.

The calculations by which these results are reached are perfectly simple and reliable, but the detail of figures would be too dry for rehearsal here, although some very curious and interesting facts might be developed thereby.\*

The precession of the equinoxes is therefore seen to be the natural and necessary result of the mechanical laws of motion, and not the result of accidental and extraneous causes, as has been taught by astronomy.

To speculate on the cause of an observed phenomenon and make a show of reason out of it is one thing, and to demonstrate the necessity of such phenomenon, its cause and exact value by a mechanical law of universal application, is quite another thing. And this is the real difference between me and the astronomers of the schools in regard to the cause of the precession of the equinoxes.

In my last published paper on this subject I said that "problems of new and exceeding interest, almost without bound, would follow the acceptance of the truth of my demonstrations." As yet I have scarcely touched upon their number or interest; others of a more startling nature than any yet mentioned, and not less clear and conclusive, are in reserve, and ready to be demonstrated whenever the principles of revolution and the value of the quadrature are admitted. These demonstrations will contradict no *known* truth, but they will add many new truths to those already known. As in the case of the precession of the equinoxes, they will set aside some of the speculative causes of the ob-

daily precession over mean time, the time being in thirds or 60ths of a second, and  $7957''' +$  expressed in the proper divisions of time =  $2' 12'' 37''' +$ , the Sun's actual daily precession in the Earth's synodical period.

\* The elements of the exact period of the Sun's orbit are, I think, developed in these calculations, which I am induced to believe is exactly 25,000 years, but with a lap or precession at the end indicative of another revolution that will take over 13,000,000 years to fulfil.

served phenomena, and substitute in their room a natural and efficient cause. They will correct false theories; and no one need be surprised if, in a very short time from this, astronomers should find themselves compelled to inquire whether they have not always been mistaken in supposing the unnatural existence of a projectile force.

Sir J. F. W. Herschell in his *Astronomy* has remarked that "Astronomy, unlike the other sciences, can never change." His meaning doubtless was, that the truths of astronomy were fixed from eternity in the laws of nature, and therein he was right, and astronomy can never change. But some who have not Herschell's perceptions of truth, have construed him to mean that the science of astronomy as taught, being already perfect in itself, can suffer no change. But this is a very great mistake. There are many things taught as truths in astronomy which are purely conjectural. I speak not now of any of the observed phenomena, but of the causes assigned for such phenomena, which are often accepted by the learned only for want of a better explanation; and if my demonstration be true, such has been the case in regard to the precession of the equinoxes; by attributing it to a wrong cause they have been led into another error to find the cause of nutation. I believe that if the principle be accepted, that the Magnetic Pole revolves by astronomical attraction—gradually, but very slowly, changing the equator and the poles—it will at once explain all those curvilinear phenomena about the Poles of the Ecliptic, which have led to the assumed cause of precession and nutation. Precession and the appearance of nutation will still exist, but the cause of them will be quite another affair. They are simple, natural, and mechanical truths, the result of a compound motion.

I do not believe the story which the savans tell us to account for precession and nutation,—that this Earth of ours, which bears us all so kindly and smoothly on her bosom, is in fact a hump-back, and that she wags herself lewdly in presence of her lord the Sun when he approaches the equator. I am satisfied that she has no such deformity or infirmity, and that she will at length vindicate herself against all such aspersions of vain and presumptuous philosophers.\*

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\* It is held by astronomers that the cause of the precession of the equinox is an accumulation of matter and protuberances of the Earth about the equator,—and that the attraction of the Sun and Moon acting upon the increased mass, gives to the Earth a disturbed motion, causing a vibratory movement on her axis, and this they call nutation or a *nodding*. I have no belief in such a cause.